Jones Group Objectives & Goals

- Identify and Characterize defects and reliability issues in III-V semiconductors after accelerated life-time testing using:
  - SEM
  - TEM
  - Atom Probe Tomography (APT)

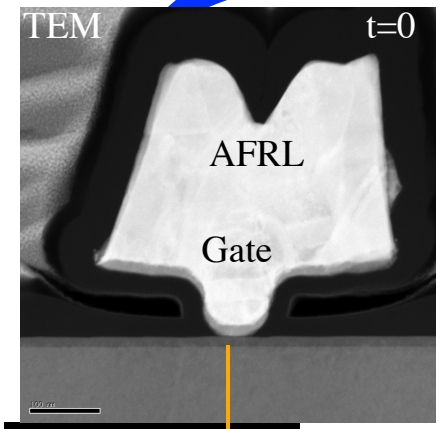
- Goals
  - Provide an understanding for the structural and chemical failure mechanisms in AlGaN/GaN HEMTs in order to improve reliability simulation.

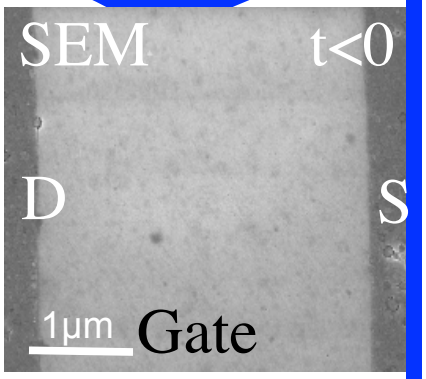
TEM, LEAP, and Interfacial Defects of AlGaN/GaN HEMTs

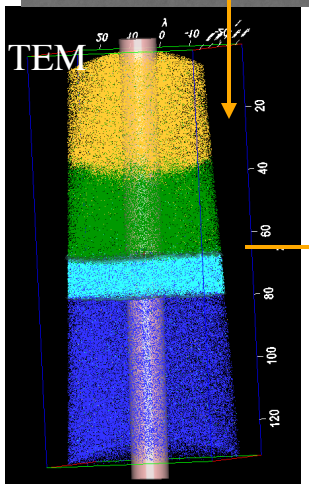
t=0, As Built

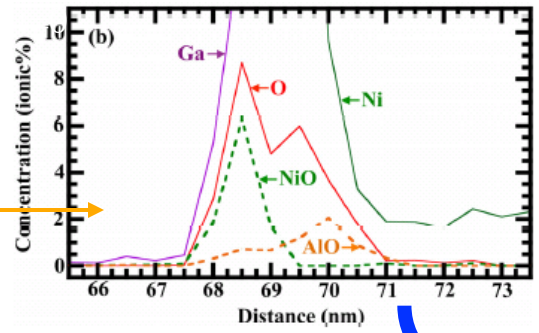
t>0, Degradation

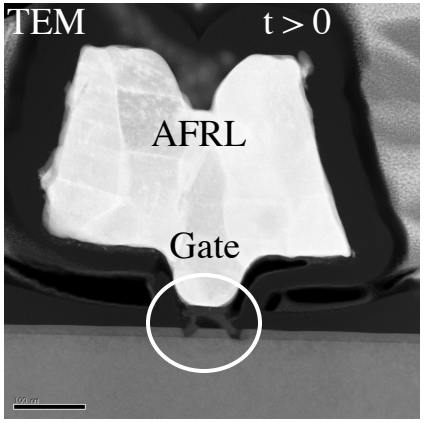
FLOORS

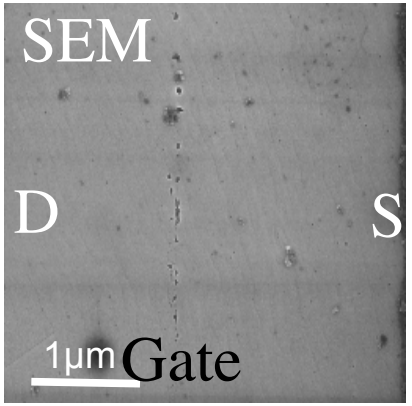




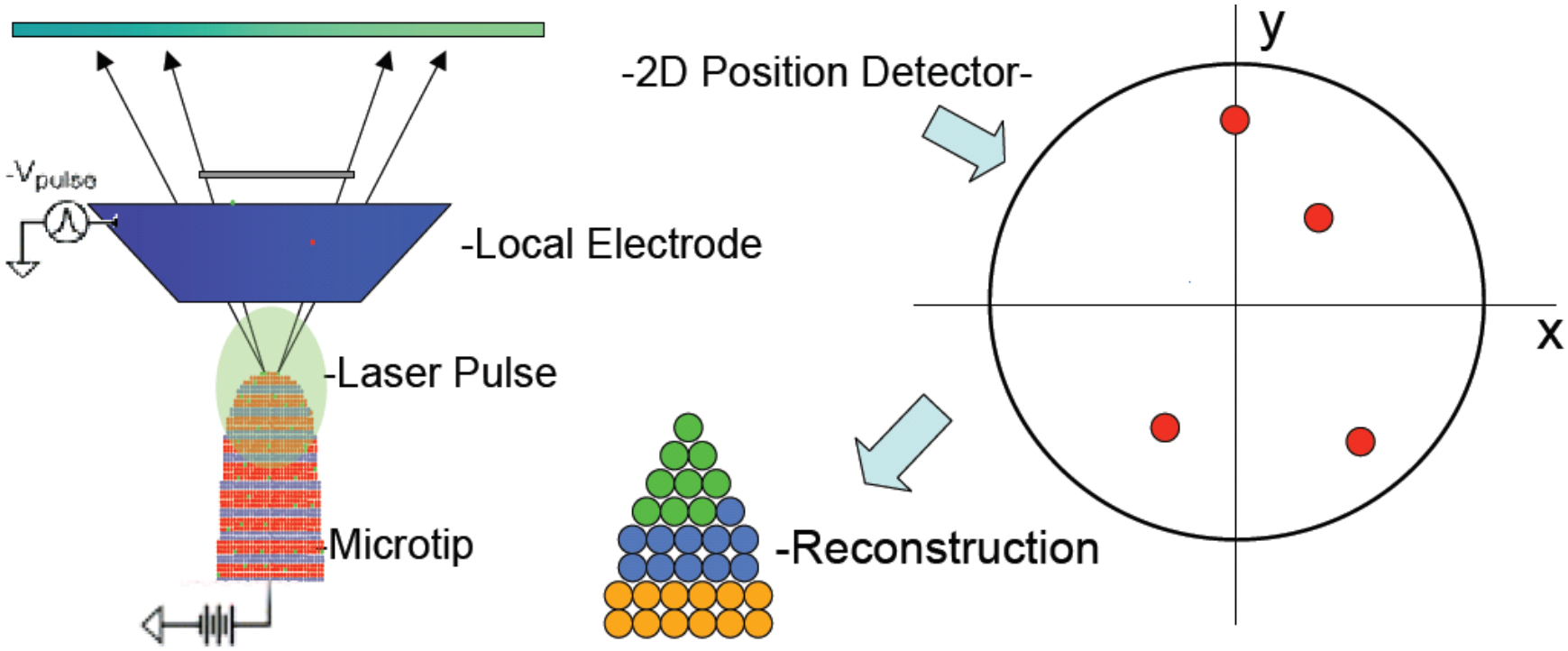








How Does APT Work?



Data collected:

- (x,y) position of impact on detector
- Impact sequence number
- Time of flight

reconstruction

Resulting analysis:

- (x,y) position of atom in plane of the tip
- Position of atom along z-axis
- Element identification

Characterize Gate Metal Reaction

- TEM (STEM-HAADF)
  - 100nm L_G
  - Ni-gate

Stress Conditions
V_{DS} = 5V
V_G = -10V to -42V
•1 min steps

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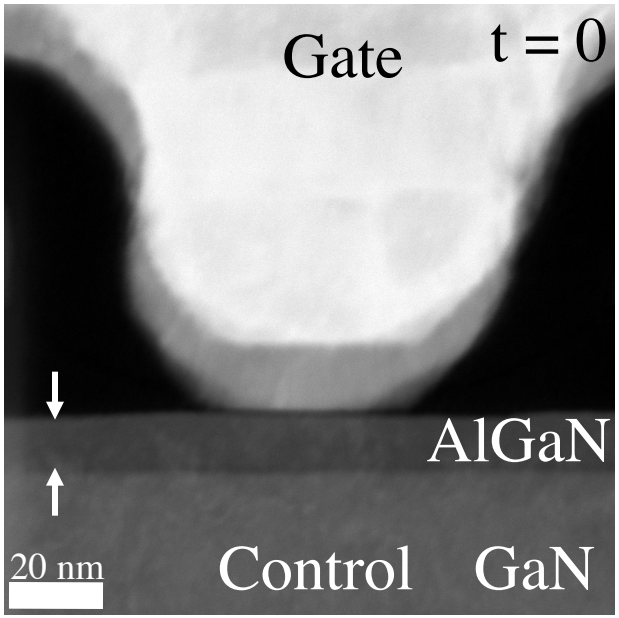
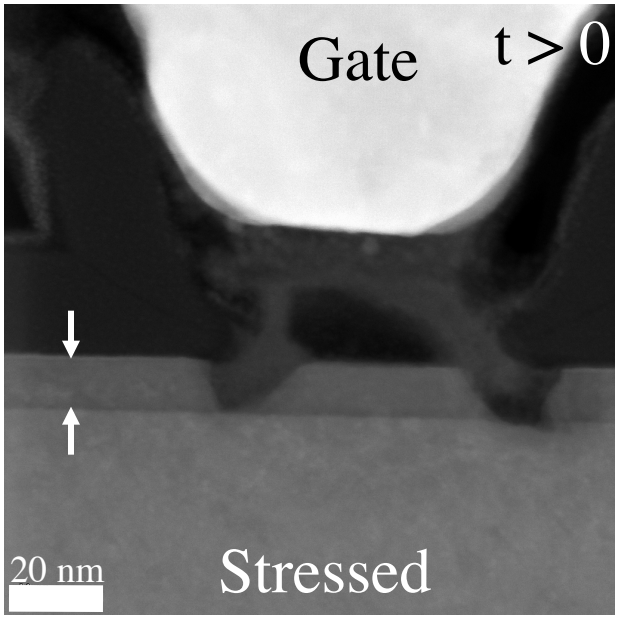
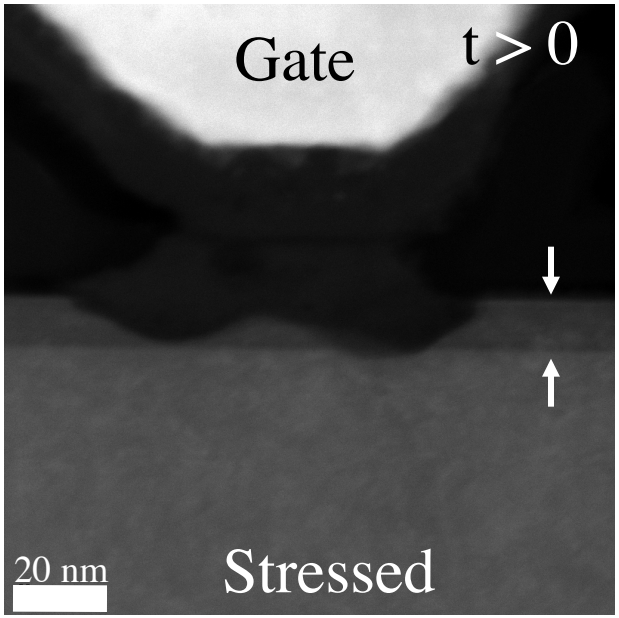






- APT would provide 3D chemical analysis and provide additional chemical information such as if segregation occurred.

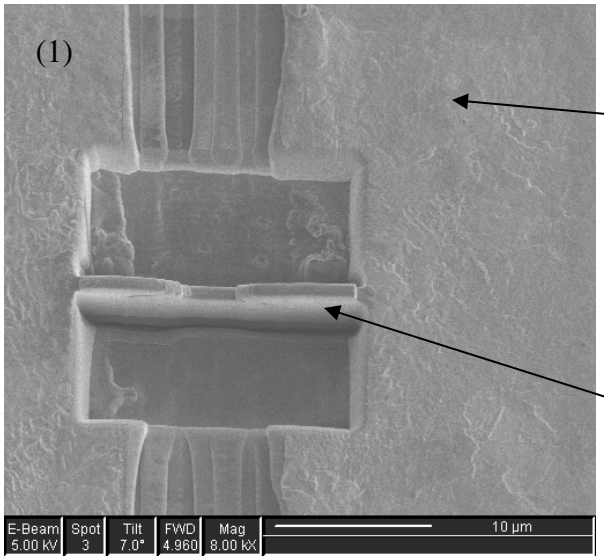
Constructing LEAP Tips of AlGaN/GaN HEMTs

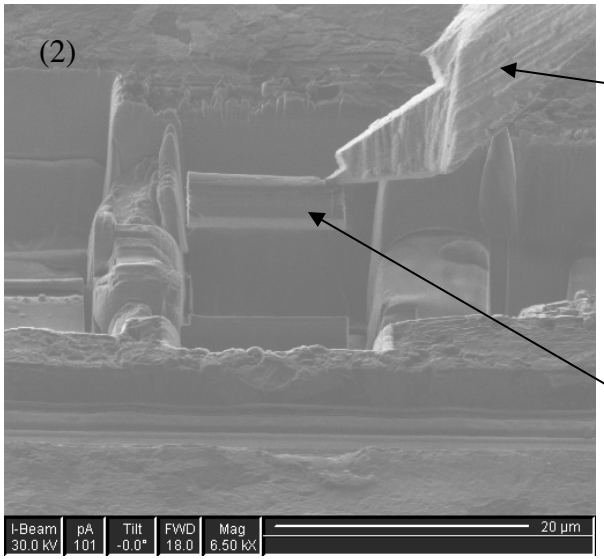
1) FIB device cross section

2) Sample lift out

3) Mount on silicon post

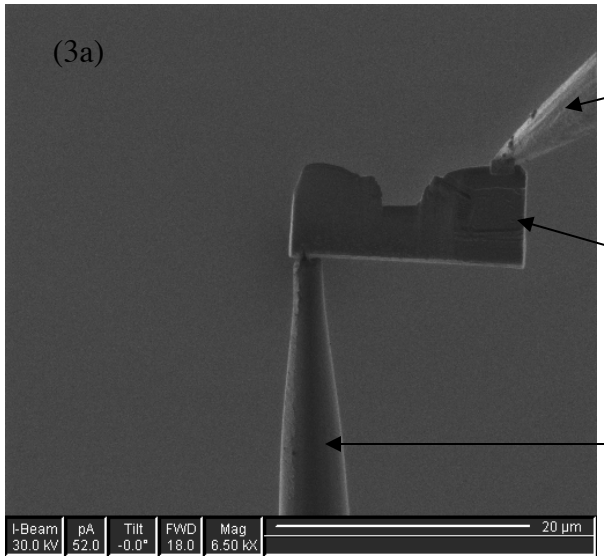
4) Sharpen tip

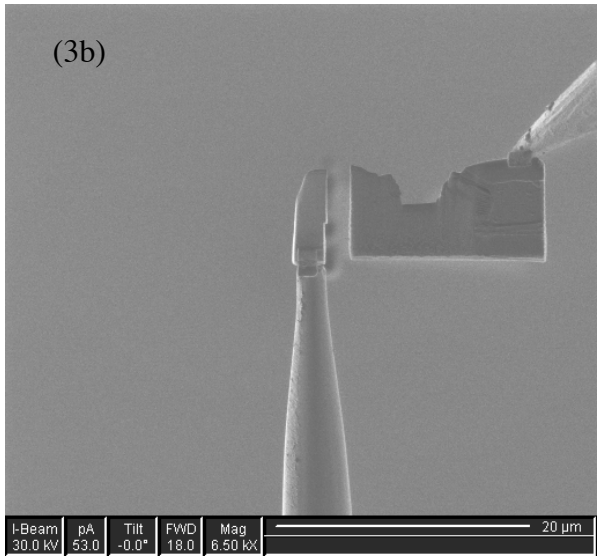




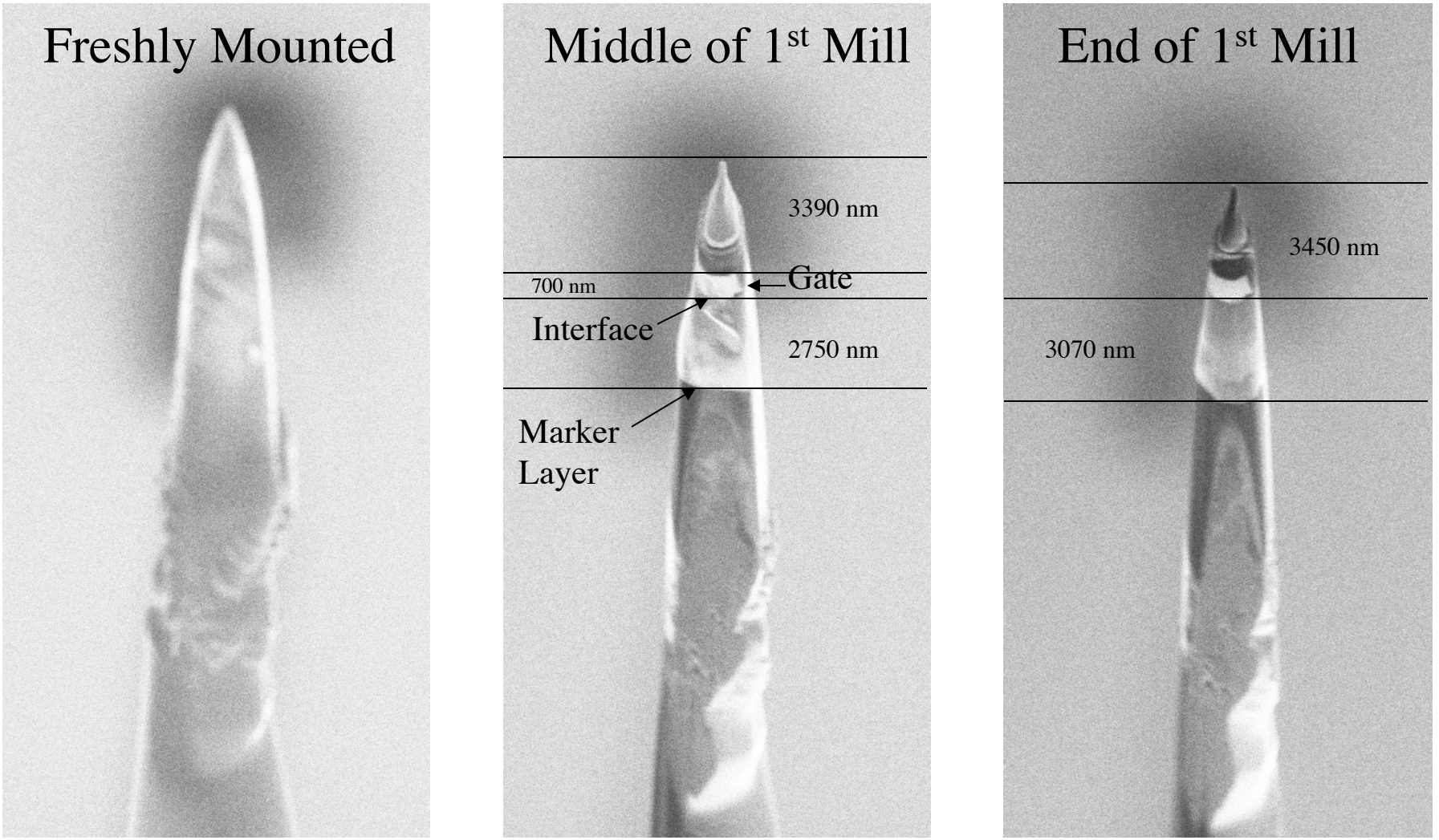
Constructing LEAP Tips

1) FIB device cross section
2) Sample lift out
3) Mount on silicon post
   a) Attach to post
   b) Detach from cross section
4) Sharpen tip

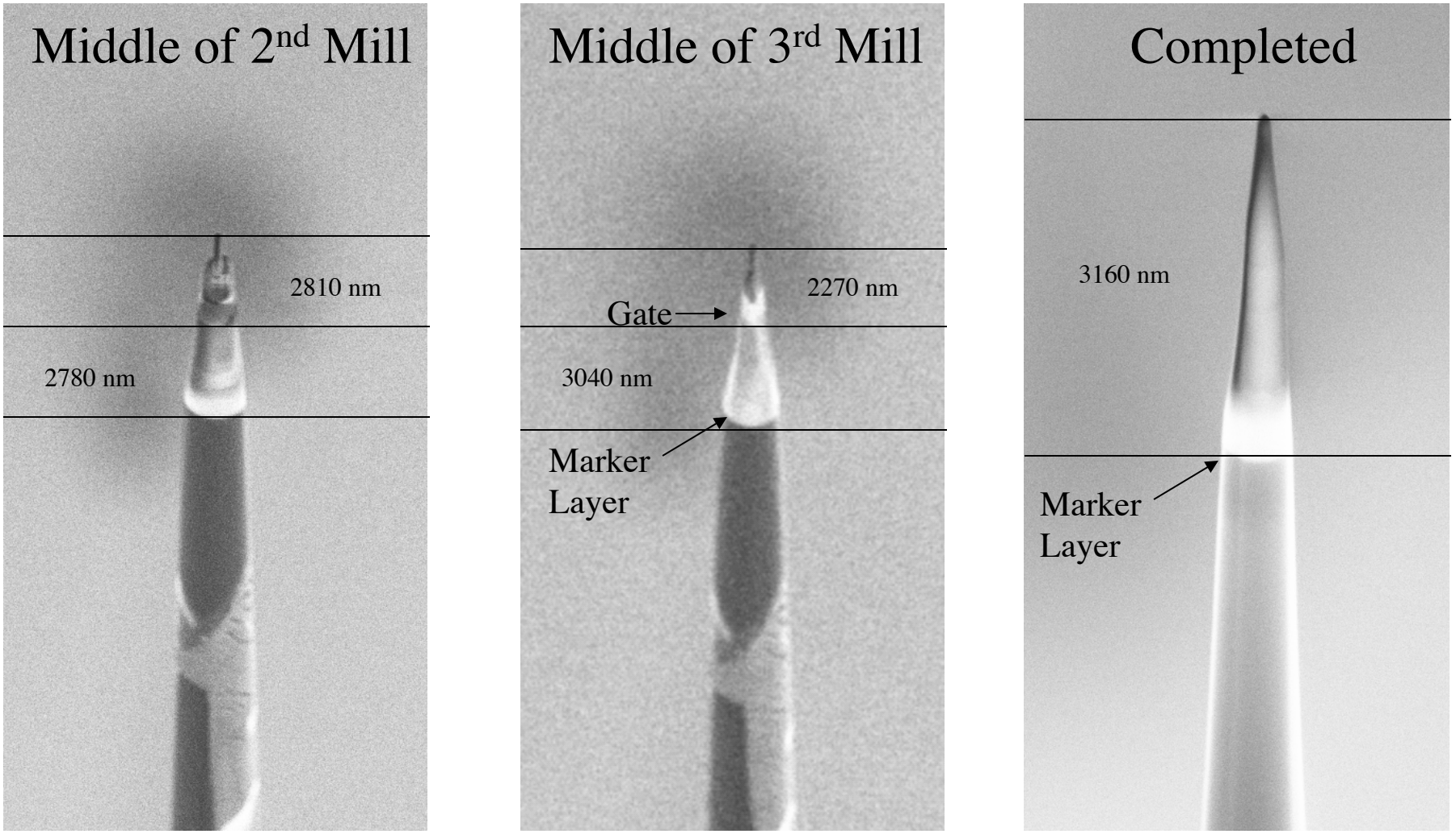




Making Site Specific LEAP Tips



Making Site Specific LEAP Tips



Analytical Instruments for Metrology

Quantitative Performance Metrics

	SIMS	TEM	APT
3D Volume Imaging	**No**	**Yes with Limitations**	**Yes**
Spatial resolution (compositional)	**50 nm laterally** **2 nm depth**	**0.2 nm laterally** **5 nm depth**	**0.4 nm laterally** **0.2 nm depth**
Image resolution	**NA**	**0.1 nm**	**0.2 nm**
Sensitivity	**<1 ppm** **(<5 x 10^{16} cm^{-3})**	**~1000 ppm** **(5 x 10^{19} cm^{-3})**	**~20 ppm** **(1 x 10^{18} cm^{-3})**
Planar specimens	**Yes**	**Yes**	**Yes**

- APT would provide 3D chemical and structural analysis on a length scale not provided by current characterization tools

Summary of Jones Group

- APT is a powerful characterization tool.
  - Used in conjunction with complimentary TEM techniques (EDS, EELS)
    - Collaborating with Prof. Hono in Tsukuba on APT
    - Collaborating with Prof. Smith ASU on EELS
- Developing Deprocessing Techniques to allow SEM studies of spatial distribution and quantification of defects.
    - Collaborating with Steve Tetlak (AFRL) on EBIC
- Various characterization methods being used to provide chemical information of sub-nm to nano-scale defects in AlGaN/GaN HEMTs and to identify defects and help propose failure mechanisms